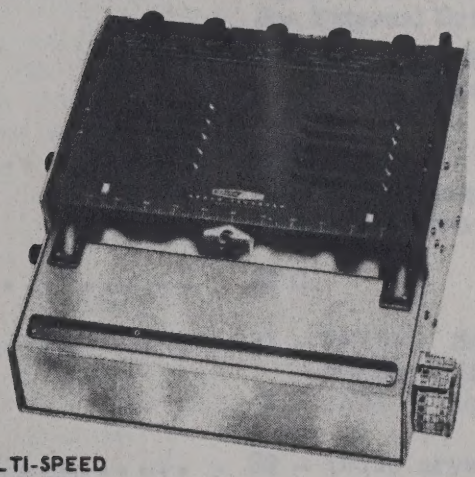
INSTALLATION AND OPERATION
OF THE HEATH
MULTI-SPEED CHART DRIVE

MODEL EU-20-26



NOTE: THE MULTI-SPEED CHART DRIVE IS SHOWN INSTALLED IN THE HEATH SERVO RECORDER.

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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

SPECIFICATIONS

Chart Speeds	5 seconds to 2 hours per inch in 21 speeds when using the internal chart drive signal. See Figure 14 on Page 13. Any chart speed up to 5 seconds per inch when using an external chart drive signal.
Chart Advancement Steps	600 steps per inch; 2 steps per cycle of the signal applied to the motor drive circuit. The motor will accurately step from 0 to 40 cps, and will run accurately at 60 cps.
External Signal Input	Input terminals for external chart drive signals. See External Drive Signals on Page 14. Input terminals for synchronization signals from other Multi-Speed Chart Drives or from other events.
Auxiliary Output Signal	Approximately 4 volts peak-to-peak square wave with 20 microseconds rise time and .2 microsecond fall time.
Auxiliary Output Impedance	68 Ω.
Transistor Complement	27 - 2N3393: Schmitt trigger, binaries, and emitter follower. 2 - 2N3416: Motor drive.
Diode Complement	29 - 1N191 crystal diode: Twenty-four binary, and five feedback diodes. 1 - 1N751 zener diode: DC level adjuster. 2 - 750 ma 100 V PIV silicon diodes: Power supply rectifiers.
Controls	21-position Chart Speed switch. External-Internal signal switch.
Power Requirements	105-125 volts AC, 60 cps, 30 watts.
Dimensions (circuit board only)	9-1/2" wide x 3-1/4" high x 1" deep.
Net Weight	3 lbs.

EXTERNAL SIGNAL CONSIDERATIONS

Sine Wave	15 cps to 10 kc, with a minimum voltage as shown in Figure 15 on Page 15.
Square Wave	0 to 10 kc, with a minimum of 3 volts peak-to-peak and maximum rise and fall times of 20 microseconds.

Pulses. . . . . 0 to 10,000 pulses per second, with a minimum amplitude dependent upon the pulse duration time.

External Signal Frequency. . . . . To obtain a chart speed other than the 21 switch-selected speeds, the required external signal frequency is calculated as follows:

$$\text{External Signal Frequency} = \frac{\text{60 X Chart Speed switch setting (SEC/IN.)}}{\text{Desired Chart Speed (SEC/IN.)}}$$

IMPORTANT: When using external signals above 60 cps, the Chart Speed switch should be set to divide the signal down to 60 cps or less. This limits the maximum chart speed to 5 seconds per inch and keeps it from exceeding the chart motor rating.

INTRODUCTION

The Multi-Speed Chart Drive provides twenty-one accurate chart speeds that are selected with the Chart Speed switch on your Heath Servo Recorder. All of the most-used chart speeds from 12 inches per minute to 1/2 inch per hour (also stated as 5 to 7200 seconds per inch) are available with this switch. The chart speeds are marked as follows on a large easy-to-read dial: seconds per inch, minutes per inch, hours per inch, inches per minute, and inches per hour.

The Chart Drive is driven by the 60 cps AC line signal. All chart speeds have the same accuracy as the frequency of this AC line signal. Since the motor drive operates on a stepping principle, the chart is advanced in a precise step for each half cycle of the chart drive signal that is applied to the motor coil. These steps of chart movement are so small (.001667 inches per half cycle) that they cannot be seen as individual steps. The chart moves one inch for every 600 half cycles of chart drive signal.

One of the reasons for using a stepping motor to drive the chart is that it allows binary division techniques to be used. These techniques, which are normally found in digital computers, are used to provide lower chart speeds that have the same accuracy as the frequency of the chart drive signal. Therefore, a wide range of chart speeds can be selected electronically by the Chart Speed switch, without the time lag and backlash problems that occur when mechanical gear trains are changed.

Another feature of the Multi-Speed Chart Drive is that it can also be driven by an external signal to provide an unlimited number of chart speeds below 12" per minute. The chart speed can be programmed by changing the frequency of the external signal according to some time sequence. The chart speed can also be synchronized with other events, or with other Heath Servo Recorders that have the Multi-Speed Chart Drive installed, by using the signal available at the auxiliary output jack.

This Multi-Speed Chart Drive unit is designed for installation in the Heath EUW-20A or EU-20B Servo Recorder and the EUW-301 Recording pH Meter. Check each part against the following Parts List and complete the steps in the Installation section of this Manual. Or, if you have purchased the Heath Model EU-20V Servo Recorder or EUW-301M Recording pH Meter, omit the Parts List and Installation sections, as this Chart Drive is completely installed and ready to operate in the Servo Recorder and pH Meter.

INTRODUCTION

OPERATION

Multi-speed operation, and methods of synchronizing this Chart Drive with other events will be explained in this section. For other information about the operation of your Heath Servo Recorder, refer to your Recorder Manual.

MULTI-SPEED OPERATION

Refer to Figures 12 and 13 to locate the controls that affect the chart speed of your Recorder. Either the internal or an external drive signal can be used to drive the chart motor.

Internal Drive Signal

The EXT-INT signal switch should be set at INT to use the 60 cps internal chart drive signal. Select the desired chart speed with the 21-position Chart Speed switch. This switch is marked so you can use any of the five calibrated scales to set the chart speed. To read the chart speed, match the color of a number shown in the window with the color of the adjacent lettering on the switch bracket. See Figure 12. Example: Turn the Chart Speed switch fully counterclockwise, match the black number 7200 with the black lettering of SEC/IN to read the chart speed of 7200 SEC/IN. At the same switch position, match the red number 2 with the red lettering of HR/IN to read the same chart speed as 2 HR/IN. This same chart speed can also be read as 0.5 IN/HR.

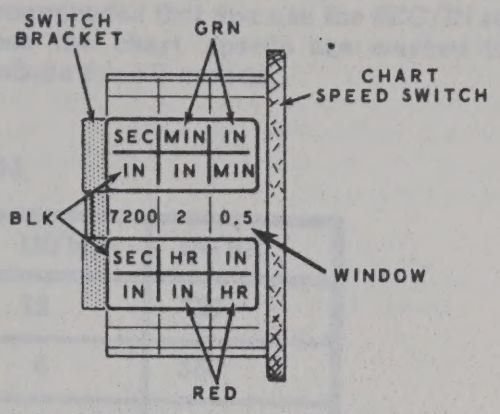


Figure 12

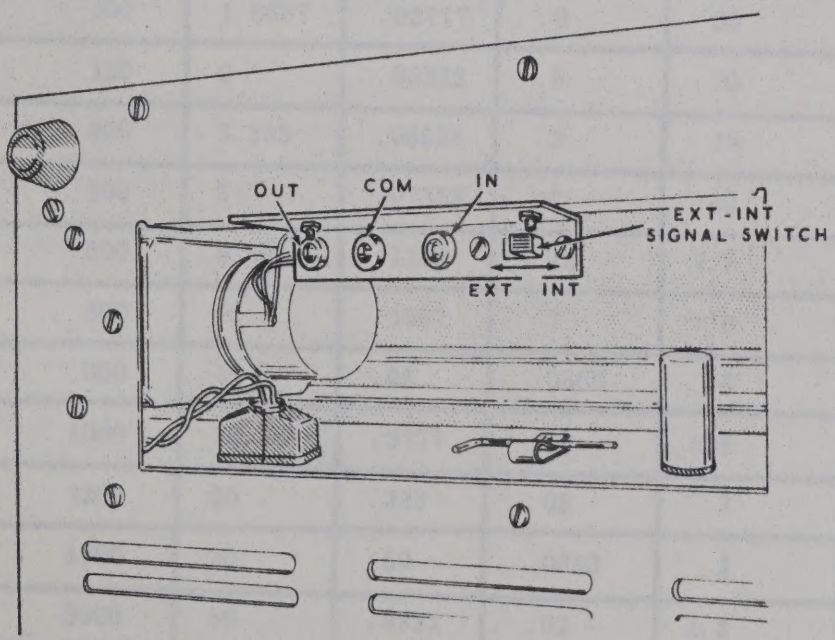
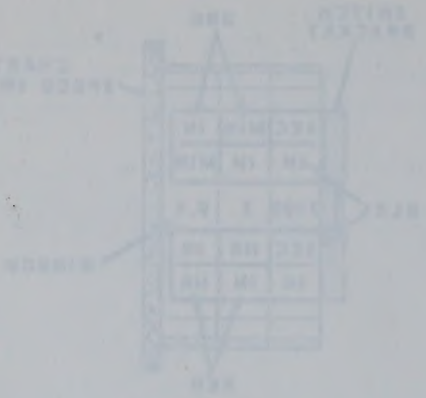
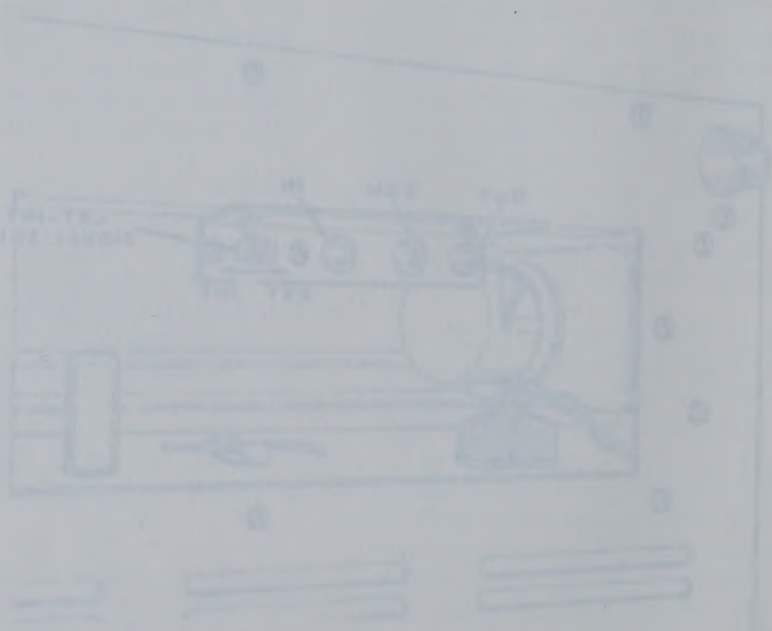


Figure 13





Note that the Chart Speed switch shows the speed in one, two, or three scales at each switch position. To read the chart speed on any scale not shown, refer to Figure 14. This Figure lists the chart speed for each of the five scales (SEC/IN; MIN/IN; IN/MIN; HR/IN; IN/HR) at all positions of the switch. Study the Figure to help determine the scale you wish to use. It is recommended that you use the SEC/IN scale because the chart speeds are marked in whole numbers for all speeds.

CHART SPEEDS

SEC/IN	MIN/IN	HR/IN	IN/MIN	IN/HR
5	.08333	.00138	12	720
10	.16667	.00277	6	360
15	.25	.00458	4	240
20	.333	.00555	3	180
30	.5	.00833	2	120
50	.83333	.01388	1.2	72
60	1	.01667	1	60
100	1.6667	.02777	.6	36
120	2	.03333	.5	30
200	3.333	.05555	.3	18
300	5	.07333	.2	12
500	8.333	.1388	.12	7.2
600	10	.1667	.1	6
900	15	.25	.0666	4
1000	16.667	.2777	.06	3.6
1200	20	.333	.05	3
1800	30	.50	.0333	2
3000	50	.8333	.02	1.2
3600	60	1	.01667	1
6000	100	1.667	.01	0.6
7200	120	2	.00833	0.5

Figure 14

External Drive Signals

Chart speeds other than those listed in Figure 14 can be selected by using an external drive signal. Speeds as fast as 5 seconds per inch as as slow as desired are possible by connecting an external drive signal in the following manner. Connect the external signal source to the IN and COM jacks as shown in Figure 13. Set the EXT-INT switch to EXT.

The external signal source can be any of the following:

1. Sine Wave - 15 cps to 10 kc with a minimum voltage as shown in Figure 15.

2. Square Wave - 0 to 10 kc with a minimum of 3 volts peak-to-peak and maximum rise and fall times of 20 microseconds.

3. Pulses - 0 to 10,000 pulses per second with a minimum amplitude dependent upon the pulse duration time.

The external drive signal should not exceed 25 volts for any type of signal.

CAUTION: Before using an external signal above 60 cps or 60 pulses per second, determine the desired chart speed and be sure to calculate the external signal frequency as given in the example that follows. Never use a chart speed faster than 5 seconds per inch, or the motor drive transistors may be damaged.

The chart speed is controlled by changing either the external signal frequency or the Chart Speed switch (or both). Chart speeds should be determined in the following manner. (Note that the chart speed can be read directly from the Chart Speed switch when the EXT-INT switch is set at INT.) With an external signal frequency of 60 cps connected to the Recorder, the chart speed can also be read directly from the switch. But when the external signal frequency is changed to other than 60 cps, the switch calibration numbers are not correct. Determine the desired chart speed; then calculate the external signal frequency with the following formula, as shown in the example.

$$\text{External Signal Frequency} = \frac{60 \text{ X Chart Speed switch setting (SEC/IN).}}{\text{Desired Chart Speed (SEC/IN)}}$$

Example: Desired Chart Speed is 18 SEC/IN. Chart Speed switch set at 120 SEC/IN.

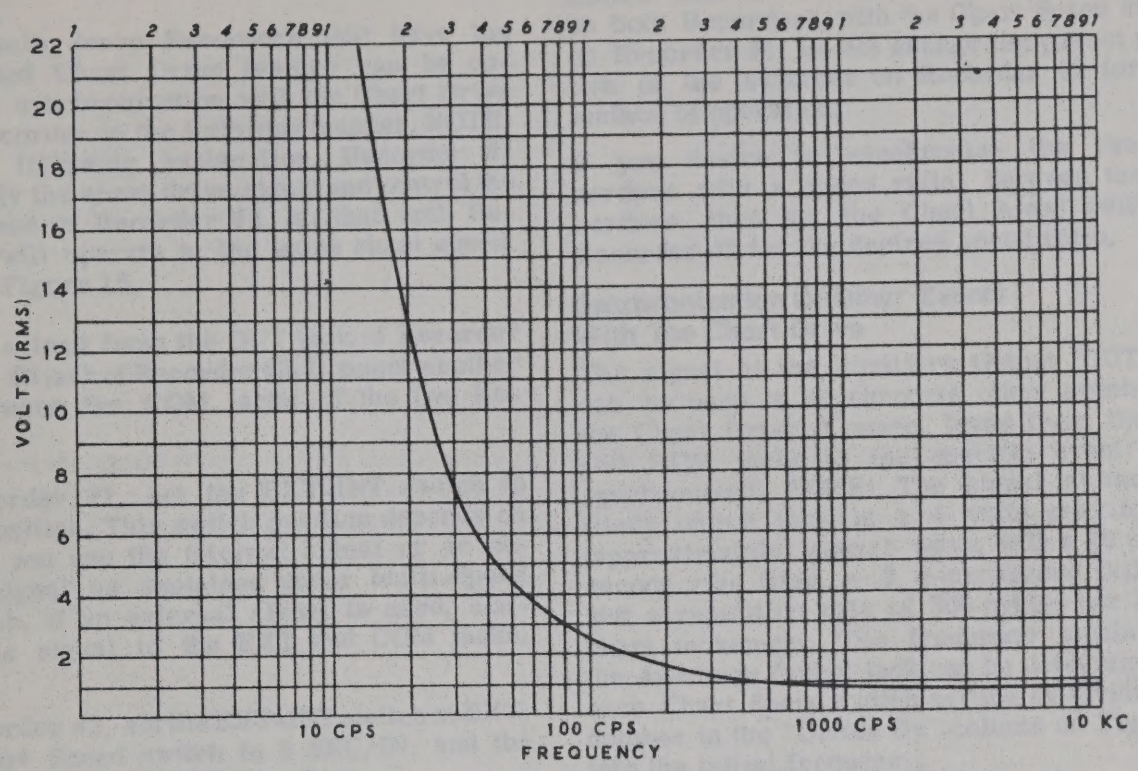
$$\text{External Signal Frequency} = \frac{60 \text{ X } 120}{18} = 400 \text{ cps.}$$

The desired chart speed in this example is 18 SEC/IN. Refer to Figure 14 and note that this chart speed cannot be selected when using the internal signal of 60 cps.

SYNCHRONIZATION

Synchronization Of Chart Drive With Other Events

The chart motor can be driven in synchronization with events that happen at certain frequencies or at individually distinct times. The synchronizing signal must come from the source of events and be connected to the IN and COM jacks, as shown in Figure 13. This signal must be within the specifications outlined previously under External Drive Signals.



MINIMUM EXTERNAL INPUT VOLTAGE (SINE WAVE)

Figure 15

Synchronization Of Other Recorders

Other Heath Servo Recorders that have the Multi-Speed Chart Drive feature can be operated in synchronization with the Chart Drive in this recorder in the following manner. NOTE: For the following explanation, Recorder #1 will supply the chart drive signal and control the chart speed of Recorder #2, so that both Recorders will operate at the same chart speed. Refer to Figure 16.

Connect a lead from the OUT jack of Recorder #1 to the IN jack of Recorder #2. Connect another lead between the COM jacks of the two Recorders.

On Recorder #1, set the EXT-INT switch to either position. This switch position depends on whether you use the internal signal or an external signal as explained under Multi-Speed Operation. If an external signal is used, connect this signal to the EXT and COM jacks.

On Recorder #2, set the EXT-INT switch at EXT, the Chart Speed switch to 5 SEC/IN, and the Power switch to the Chart position.

Now the Power switch on Recorder #1 will control both Recorders. Control the chart speed on both Recorders with the Chart Speed switch on Recorder #1. Do not change the preset position of the switches on Recorder #2 for this method of operation.

If you desire to synchronize the two Recorders with a speed ratio between the Recorders, then set the Chart Speed switch on Recorder #2 for the desired speed ratio.

Synchronization Of Other Events With The Chart Drive

The signal at the Auxiliary Output (OUT) jack can be used to synchronize other events with the Chart Drive. Connect leads from the OUT and COM jacks to the specific event to be synchronized. NOTE: The signal at the auxiliary output jack is a 4 volts peak-to-peak (approximately) square wave, with a 20 microsecond rise time, a .2 microsecond fall time, and a repetition rate of 300 cycles per inch of chart movement. The frequency available at the Auxiliary Output jack can be determined for each Chart Speed switch setting by dividing the number in the "Divide By" column on Figure 18 into the initial frequency.

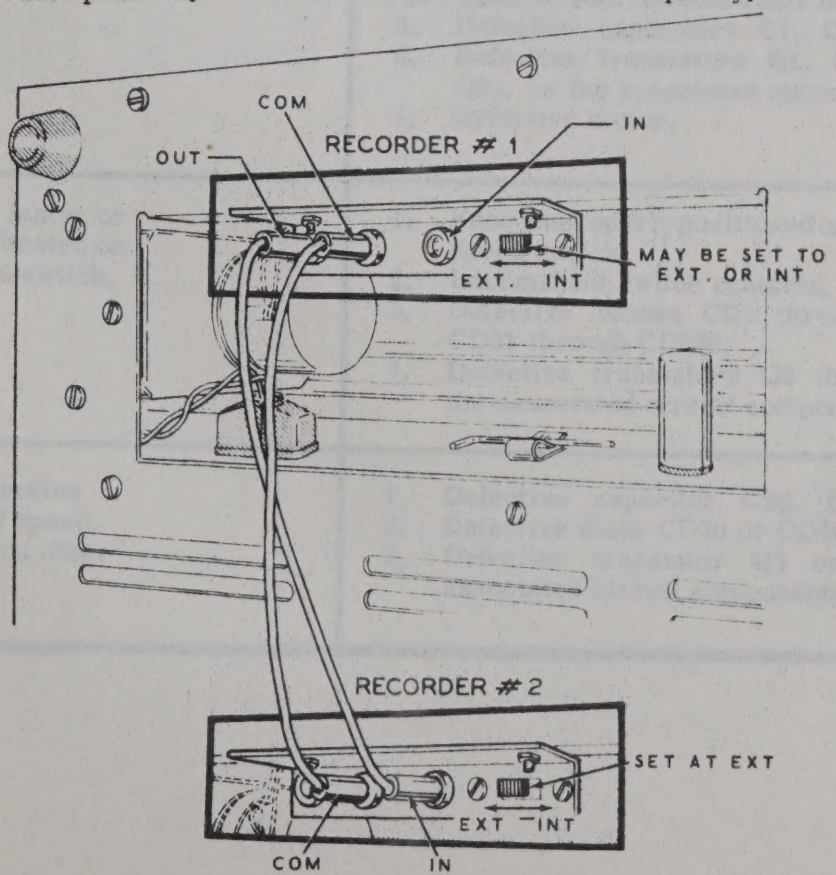
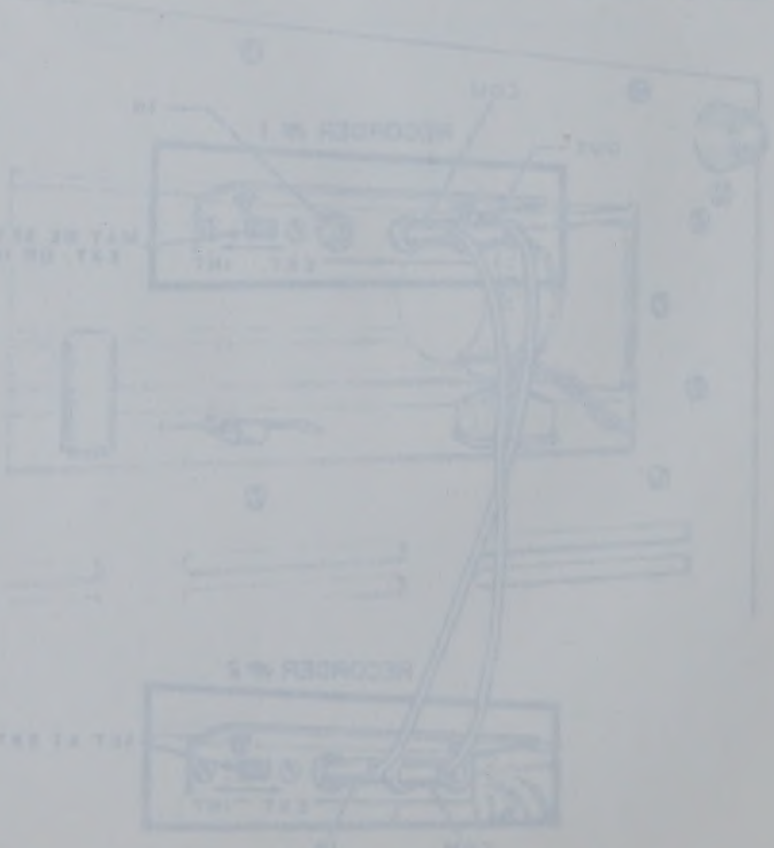


Figure 16



IN CASE OF DIFFICULTY

1. Refer to the Troubleshooting Chart to help locate the difficulty. The Circuit Board X-Ray View shows the location of the components with respect to the component side of the circuit board. The R and C numbers correspond to the R and C numbers on the Schematic.
2. If, after careful checks, the trouble is still not located and a DC oscilloscope is available, check the waveforms against those shown on the Schematic.
3. A review of the Circuit Description may be helpful in indicating where to look for the cause of the trouble.

Troubleshooting Chart

TROUBLE	POSSIBLE CAUSE
Chart motor inoperative.	1. Check position of EXT-INT signal switch. 2. Be sure the AC plug from the power transformer is plugged into the AC socket of the Recorder. 3. Make sure the motor gear is not overmeshed and binding with the clutch drive gear on the Recorder. 4. Open or shorted diode SD1 or SD2. 5. Defective capacitors C1, C280, or C290. 6. Defective transistors Q1, Q2, Q27, Q28, Q29, or the associated circuit components. 7. Defective motor.
Chart speed is faster or slower than indicated on the Chart Speed switch.	1. Knob improperly positioned on shaft of Chart Speed switch. 2. Intermittent switch contacts. 3. Defective diodes CD1 through CD5, and CD31 through CD260. 4. Defective transistors Q3 through Q26 or the associated circuit components.
Chart motor operates OK on 5 SEC/IN speed, but inoperative on other speeds.	1. Defective capacitor C20, C30, or C40. 2. Defective diode CD30 or CD40. 3. Defective transistor Q3 or Q4, or the associated circuit components.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Figure 17) and the Schematic (fold-out from Page 21) while reading the following Circuit Description. This description is divided into sections that correspond to the individual circuits of the Multi-Speed Chart Drive.

SCHMITT TRIGGER

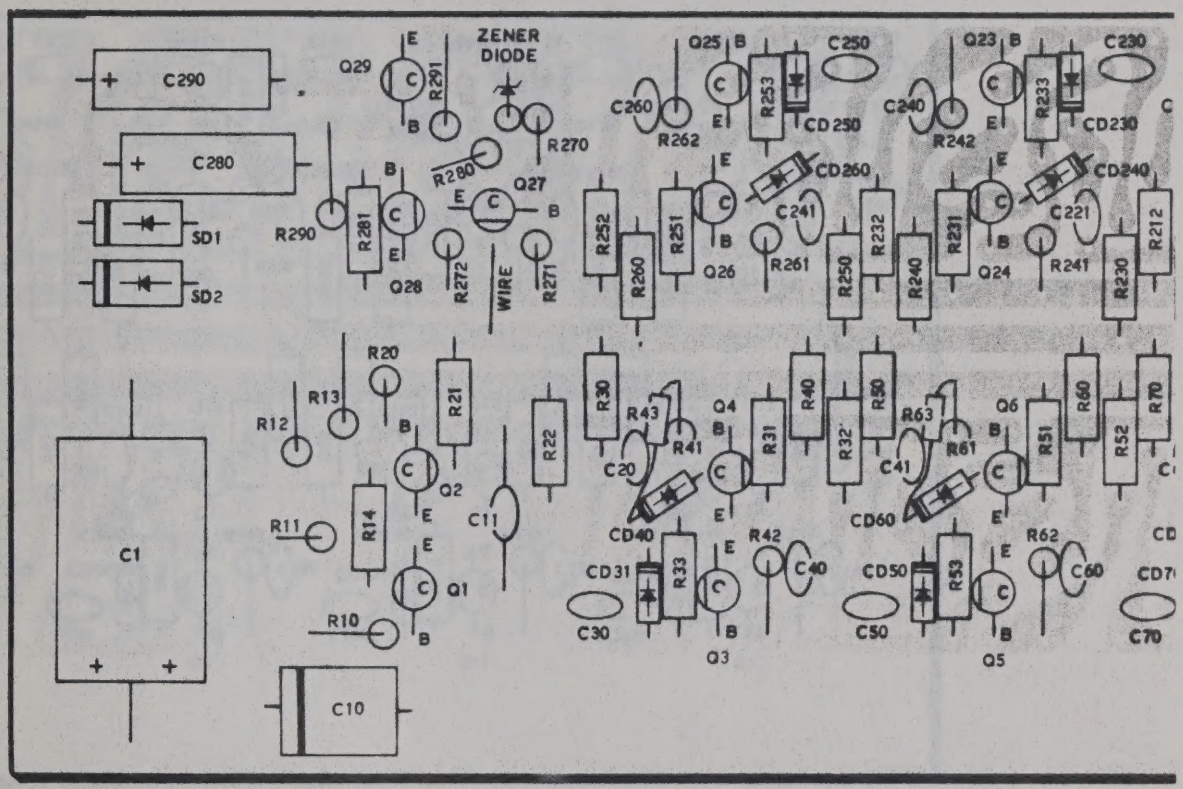
A chart drive signal is coupled from Ext-Int switch S1 to the base of transistor Q1. With switch S1 at Int, a 60 cps sine wave signal is taken from the secondary of power transformer T1. With switch S1 at Ext, an external chart drive signal is taken from the In and Com jacks.

Transistor stages Q1 and Q2 form a Schmitt Trigger circuit. The output signal from this circuit is always a square wave, regardless of the type of waveform used as the chart drive the type of waveform used as the input signal. The Schmitt Trigger circuit operates as follows: The positive pulse of the input signal causes Q1 to conduct, and Q2 is then cut off. When the signal goes negative, Q1 is cut off and Q2 starts conducting again. This switching occurs rapidly due to the regenerative feedback of the common emitter resistor, R22. The rapid switching action causes the signal at the collector of Q2 to be a square wave.

With the Chart Speed switch at 5 SEC/IN, the binary circuits are not used, and the signal from the collector of Q2 is connected through lugs 12 and 14 of switch wafer 3R to the input of emitter follower transistor Q27. The binary circuits will be explained later.

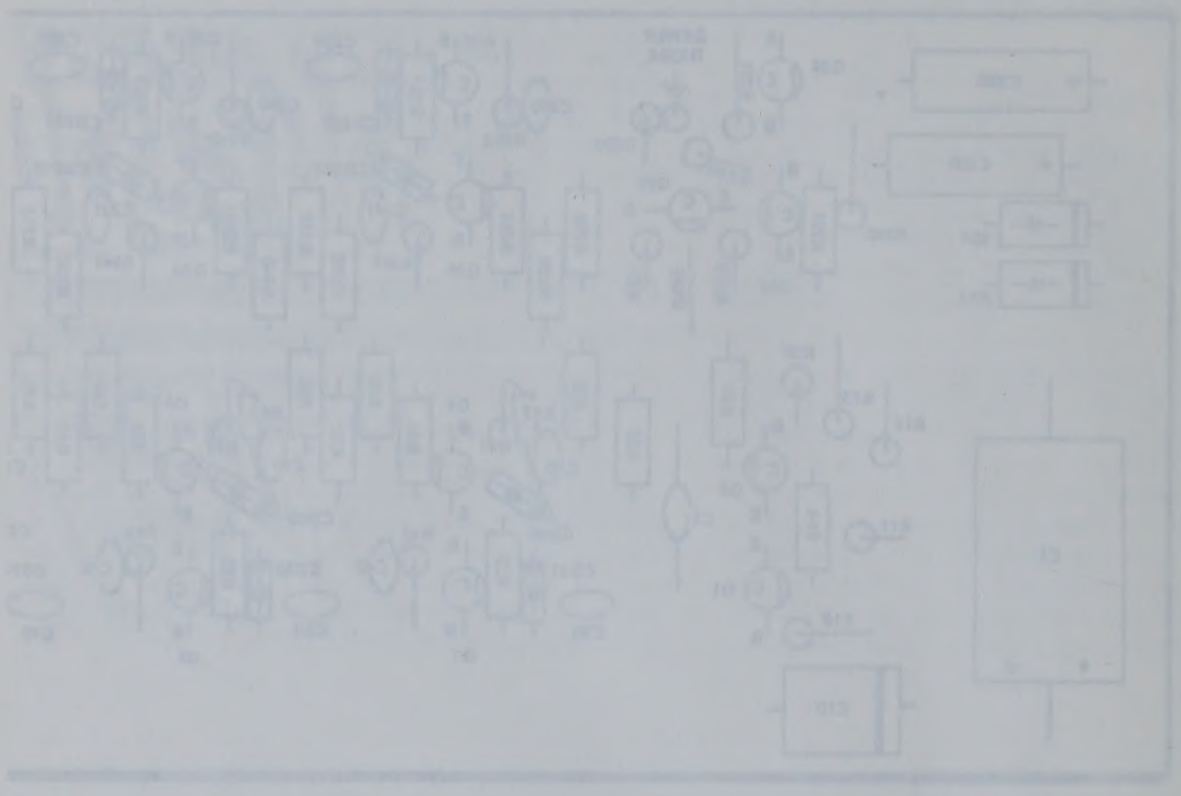
EMITTER FOLLOWER

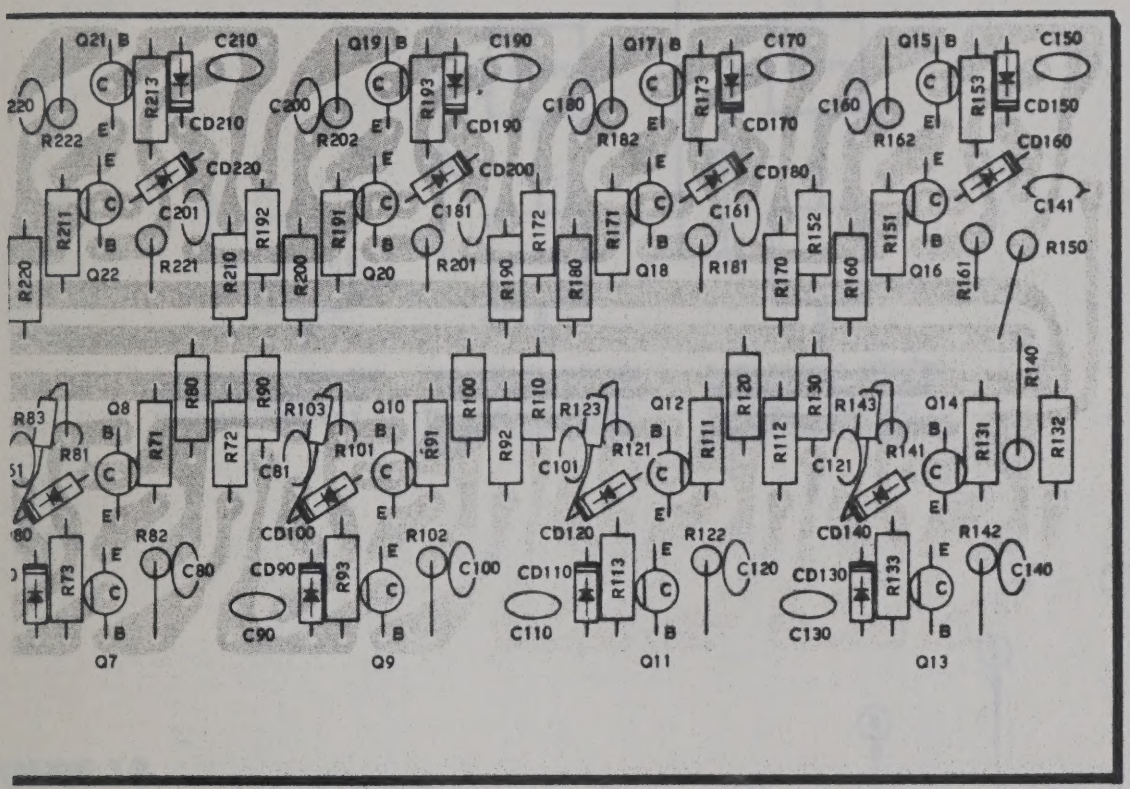
Transistor stage Q27 is an emitter follower that isolates the Schmitt Trigger and the binaries from the motor drive circuit and the Auxiliary Output jack. The square wave signal coming from lug 14 of the Chart Speed switch, is coupled through the zener diode and resistor R270 to the base of Q27. The zener diode is a DC level adjuster that controls the bias voltage on the base of Q27. The signal is then coupled from the emitter of Q27 through resistor R280 to the motor drive circuit.



CIRCUIT BOAR

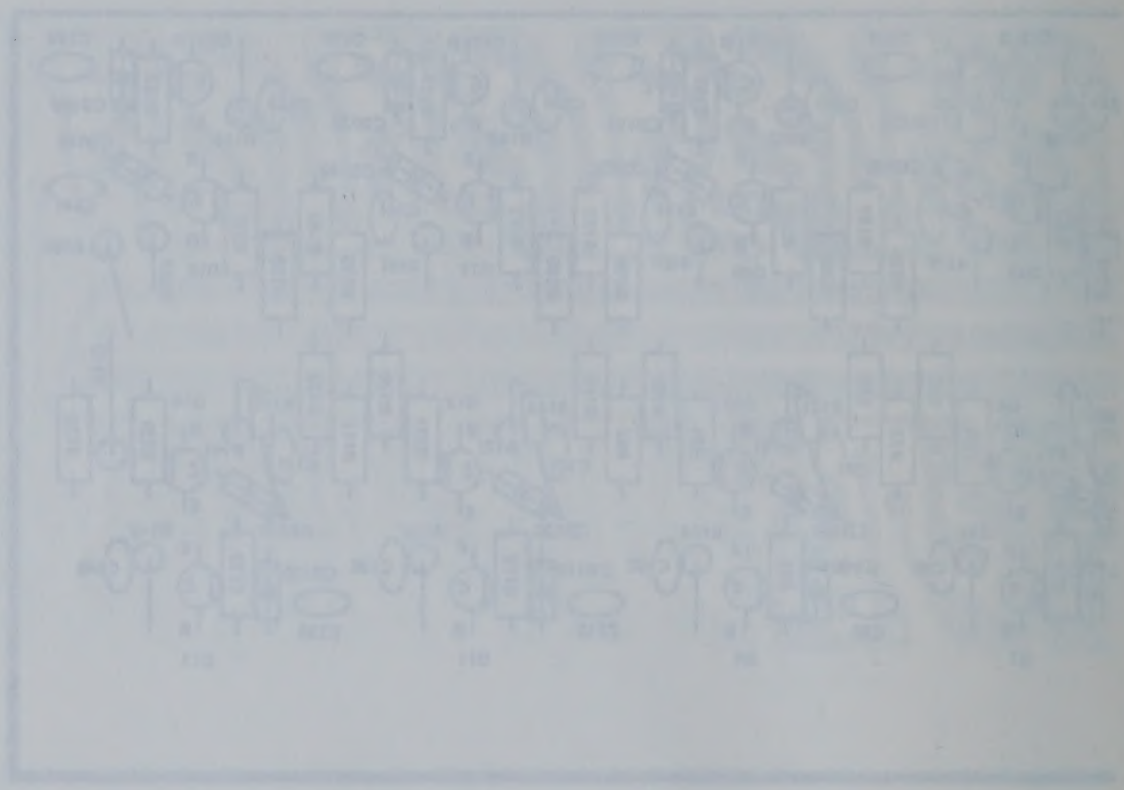
(VIEWED FROM





RD X-RAY VIEW

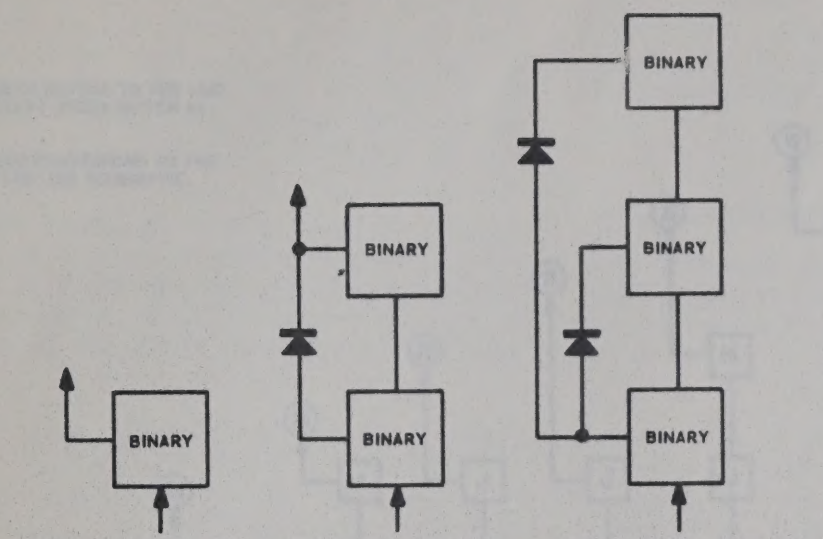
COMPONENT SIDE)



NOTES:

1. ◯ THIS SYMBOL AROU NUMBER ON WAFER 3R SHOWN ON THE SCHEMA

2. CRYSTAL DIODES CD1 T DIODES WITH THE SAME



EACH BINARY DIVIDES THE SIGNAL FREQUENCY AND THE CHART SPEED BY 2.

TWO BINARIES, WITH ONE FEEDBACK DIODE, DIVIDE THE SIGNAL FREQUENCY AND THE CHART SPEED BY 3.

THREE BINARIES, WITH TWO FEEDBACK DIODES, DIVIDE THE SIGNAL FREQUENCY AND THE CHART SPEED BY 5.

FIGURE 18

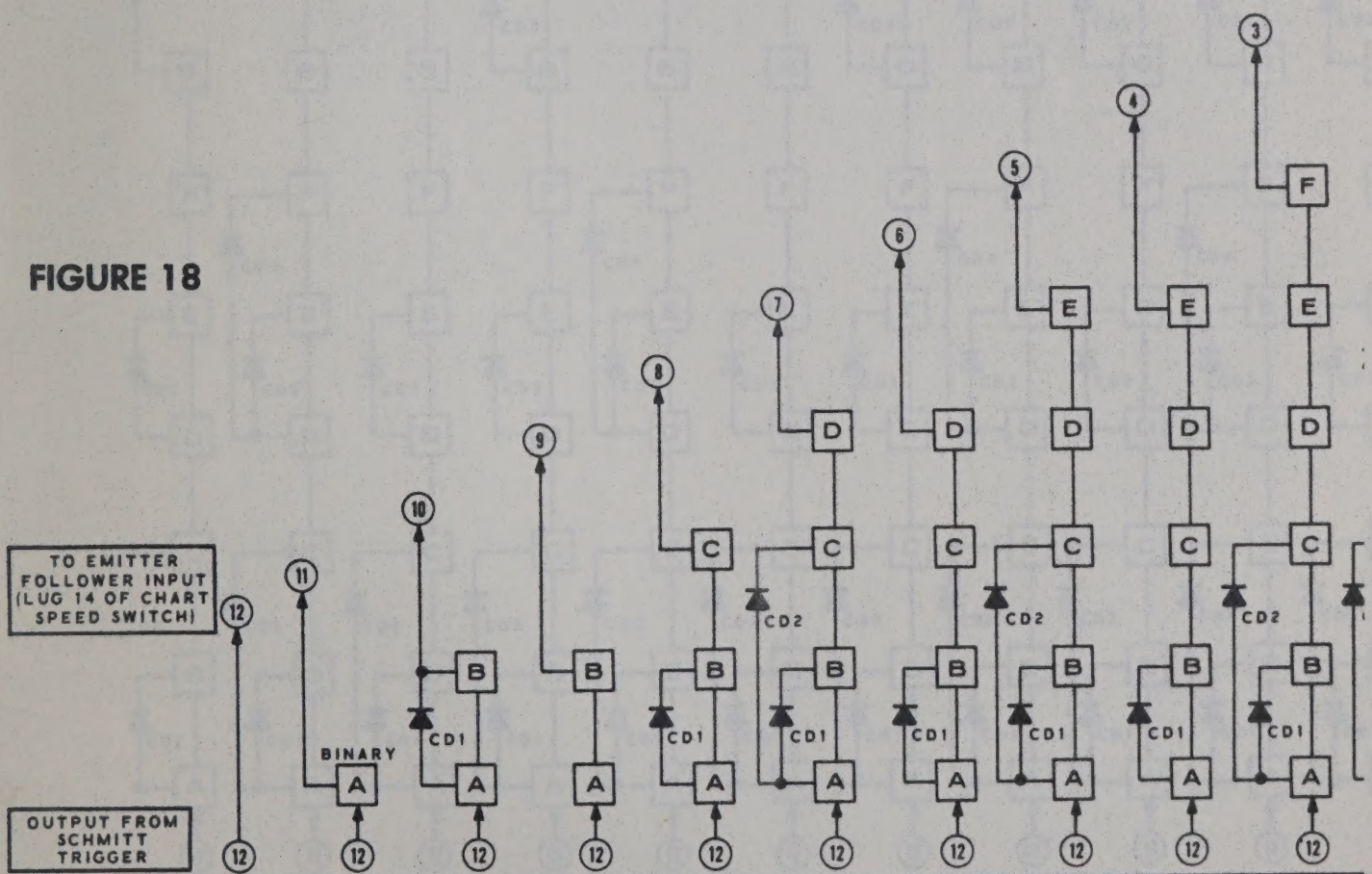
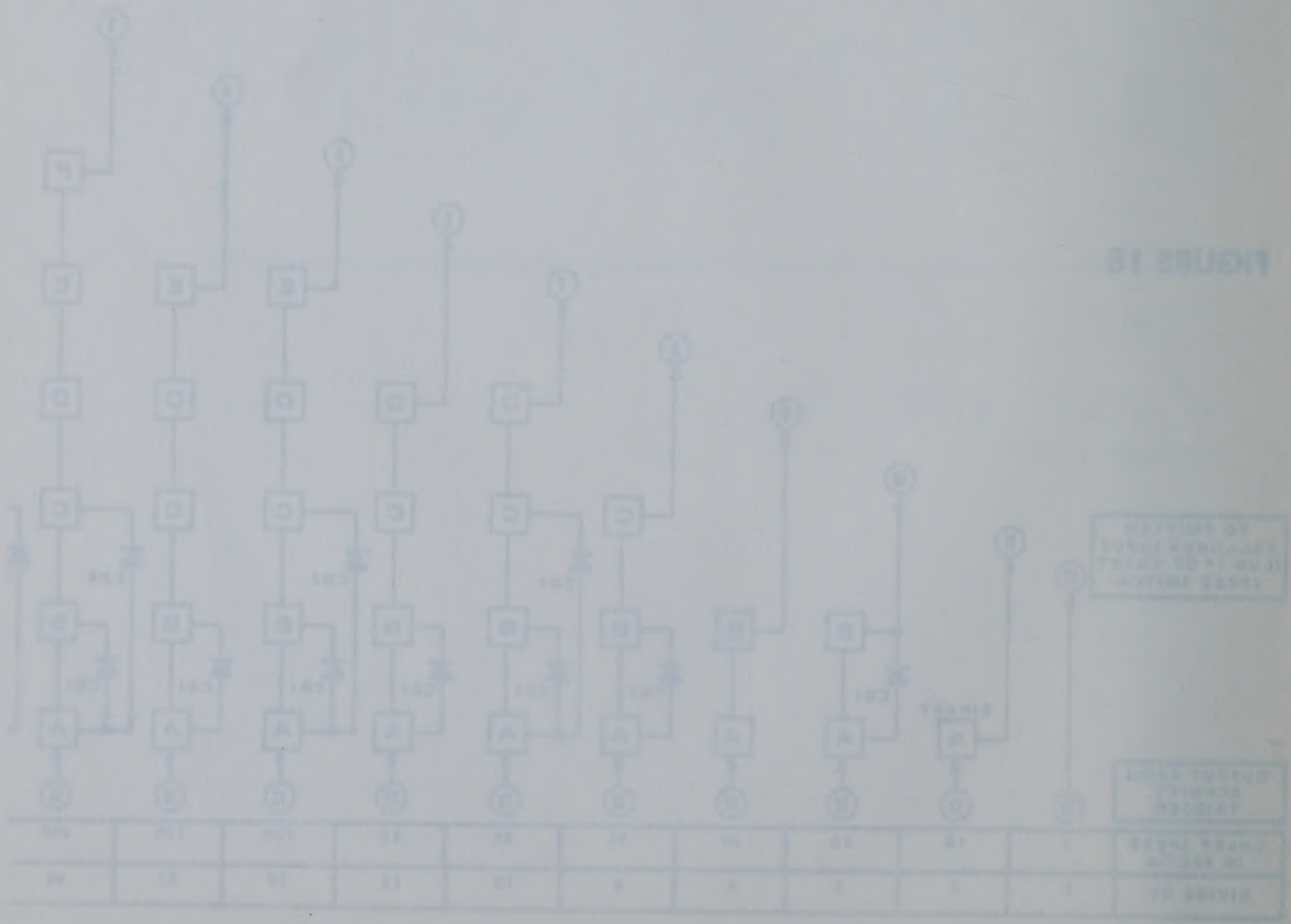
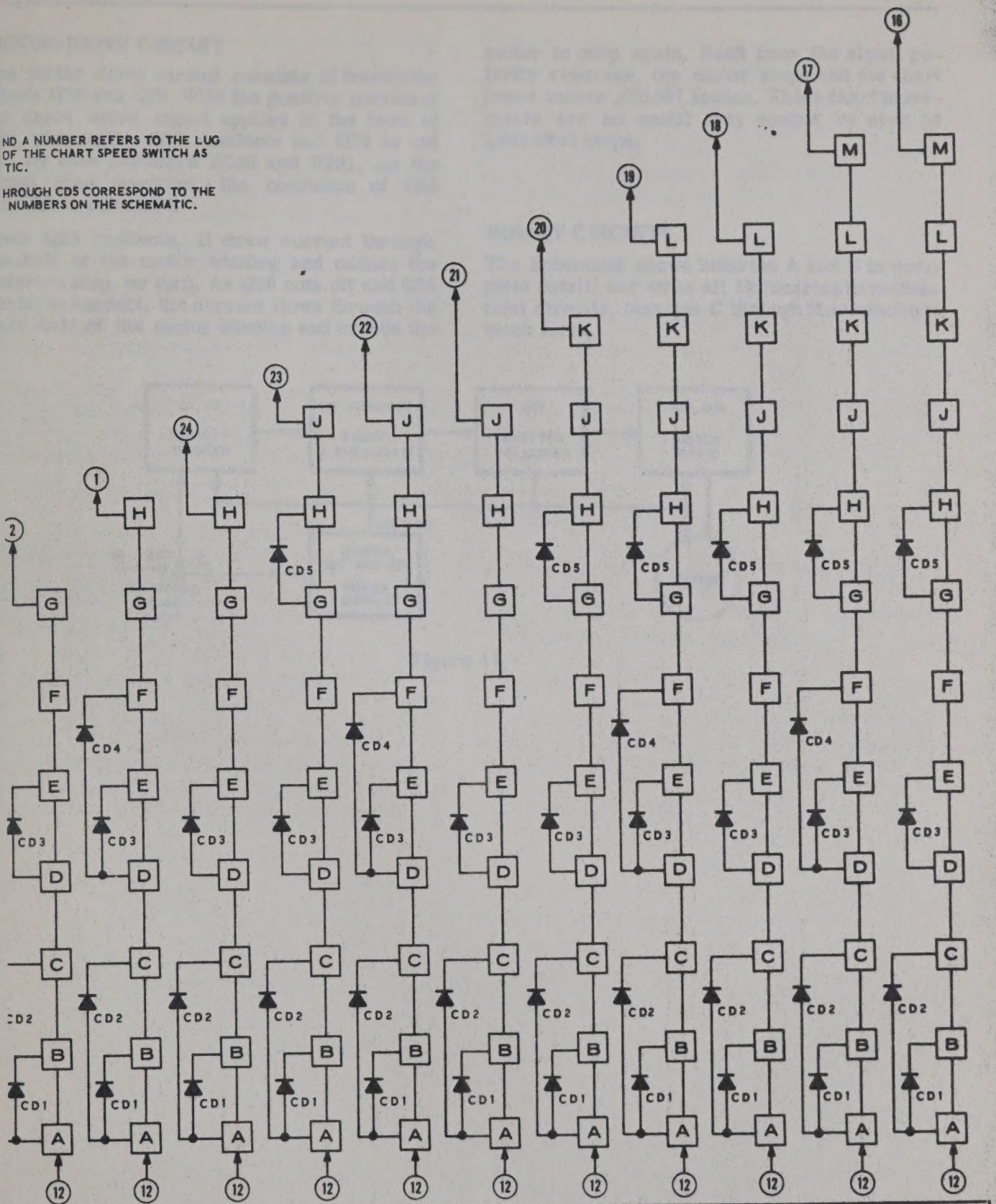


CHART SPEED IN SEC/IN	5	10	15	20	30	50	60	100	120	200
DIVIDE BY	1	2	3	4	6	10	12	20	24	40



ND A NUMBER REFERS TO THE LUG OF THE CHART SPEED SWITCH AS TIC.

HROUGH CD5 CORRESPOND TO THE NUMBERS ON THE SCHEMATIC.



300	500	600	900	1000	1200	1800	3000	3600	6000	7200
60	100	120	180	200	240	360	600	720	1200	1440

MOTOR DRIVE CIRCUIT

The motor drive circuit consists of transistor stages Q28 and Q29. With the positive portion of the chart drive signal applied to the base of Q28, transistor Q28 conducts and Q29 is cut off, by bias resistors R290 and R291. As the signal goes negative, the operation of Q28 and Q29 is reversed.

When Q28 conducts, it draw current through one-half of the motor winding and causes the motor to step, or turn. As Q28 cuts off and Q29 starts to conduct, the current flows through the other half of the motor winding and causes the motor to step again. Each time the signal polarity reverses, the motor steps and the chart paper moves .001667 inches. These chart movements are so small they cannot be seen as individual steps.

BINARY CIRCUITS

The Schematic shows binaries A and B in complete detail; and since all 12 binaries have identical circuits, binaries C through M are shown in block form.

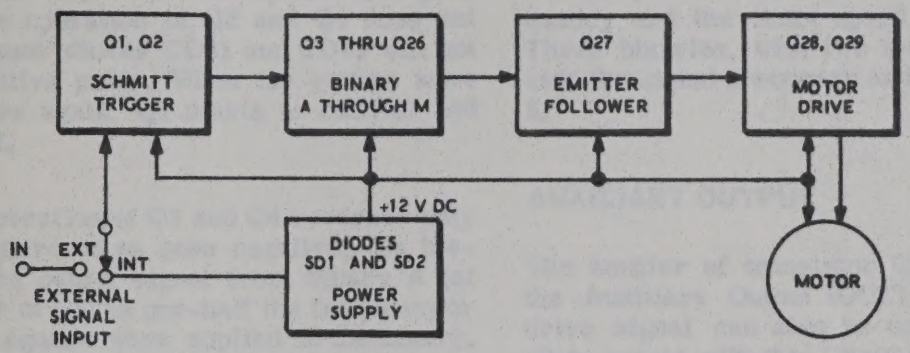


Figure 17

One or more binaries are connected in the circuit by the Chart Speed switch to decrease the rate that the chart drive signal reverses polarity. This lower rate of polarity change, in turn, decreases the speed of the chart motor.

With the Chart Speed switch set at 10 SEC/IN, binary A is connected in the circuit and operates in the following manner: The square wave signal is coupled from the collector of transistor Q2, through capacitor C20, to the junction of diodes CD31 and CD40. Assume that transistor Q3 is cut off and Q4 is conducting until the square wave is applied to this circuit. When the square wave goes negative, Q3 starts conducting and Q4 is cut off. When the square wave goes positive, the operation of Q3 and Q4 does not change because diodes CD31 and CD40 will not pass a positive pulse. When the square wave goes negative again, Q4 starts to conduct and Q3 is cut off.

Since the operation of Q3 and Q4 reverses only when the square wave goes negative, the frequency of the output signal from binary A (at the collector of Q3) is one-half the frequency or rate of the square wave applied to the binary.

The output signal of binary A is coupled from the collector of Q3, to lugs 11 and 14 of the Chart Speed switch. This signal is then coupled to emitter follower Q27, and to the motor drive circuit. The motor drive circuit in turn drives the chart motor. The motor speed has now been reduced to one-half it original speed by binary A.

When the Chart Speed switch is turned to 20 SEC/IN, binaries A and B are connected in the circuit. Binary A divides the signal frequency by 2 and binary B divides the signal frequency by 2 again. The original signal frequency coming from the Schmitt Trigger circuit is now divided by 4, which results in a chart speed that is one-fourth the original speed.

Figure 18 (fold-out from Page 18) shows the binary connections for the 21 positions of the Chart Speed switch. As explained above, each binary divides the signal frequency and chart speed by 2. When two binaries are used with a feedback diode (diodes CD1 through CD5) connected between them, the input signal frequency and the chart speed are divided by 3. Three binaries, with two feedback diodes, divide the signal frequency and the chart speed by 5.

AUXILIARY OUTPUT

The emitter of transistor Q27 is connected to the Auxiliary Output (OUT) jack so the chart drive signal can also be used to synchronize other events with this Chart Drive.

POWER SUPPLY

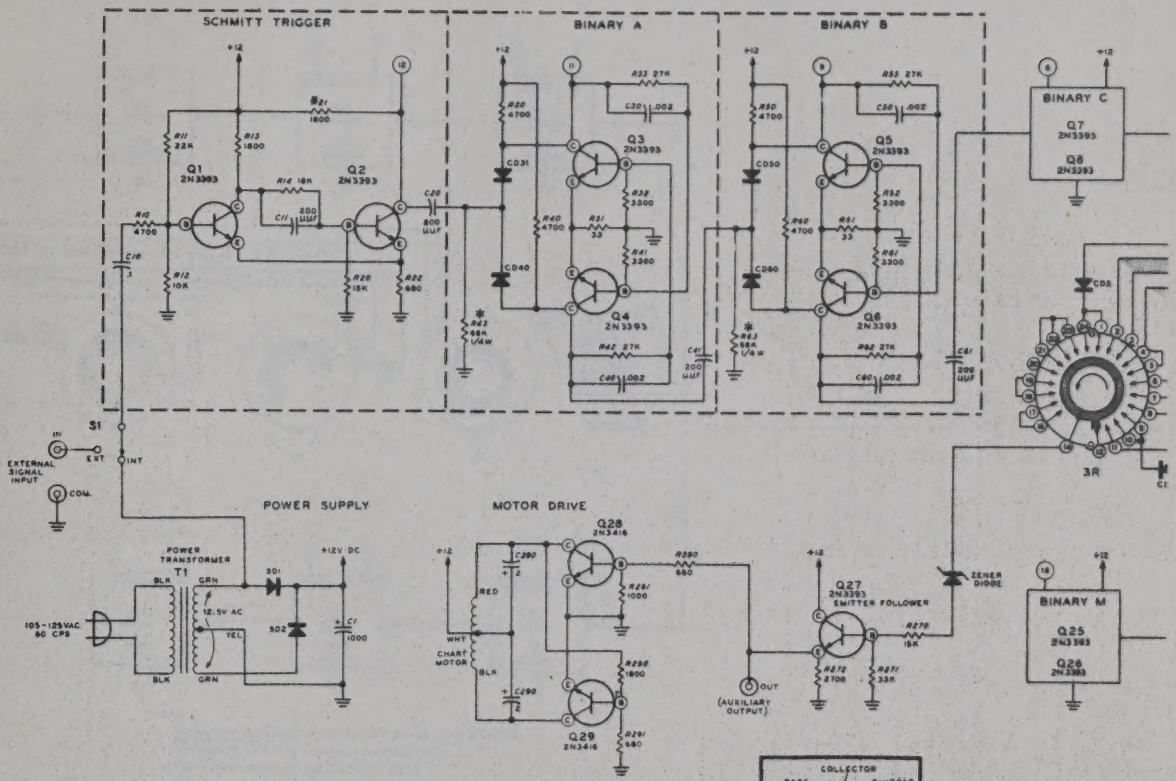
The transformer-operated power supply uses diodes SD1 and SD2 as a full-wave rectifier. Capacitor C1 removes AC ripple from the +12 V DC supply voltage before it is connected to the other circuits.

REPLACEMENT PARTS LIST

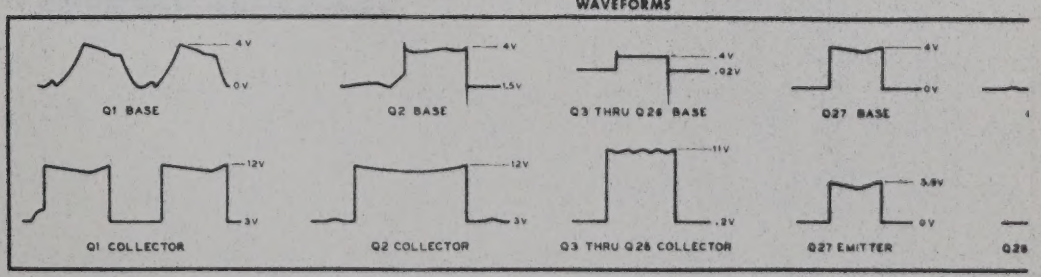
Write to the Heath Company for replacement price information for any of the following parts.

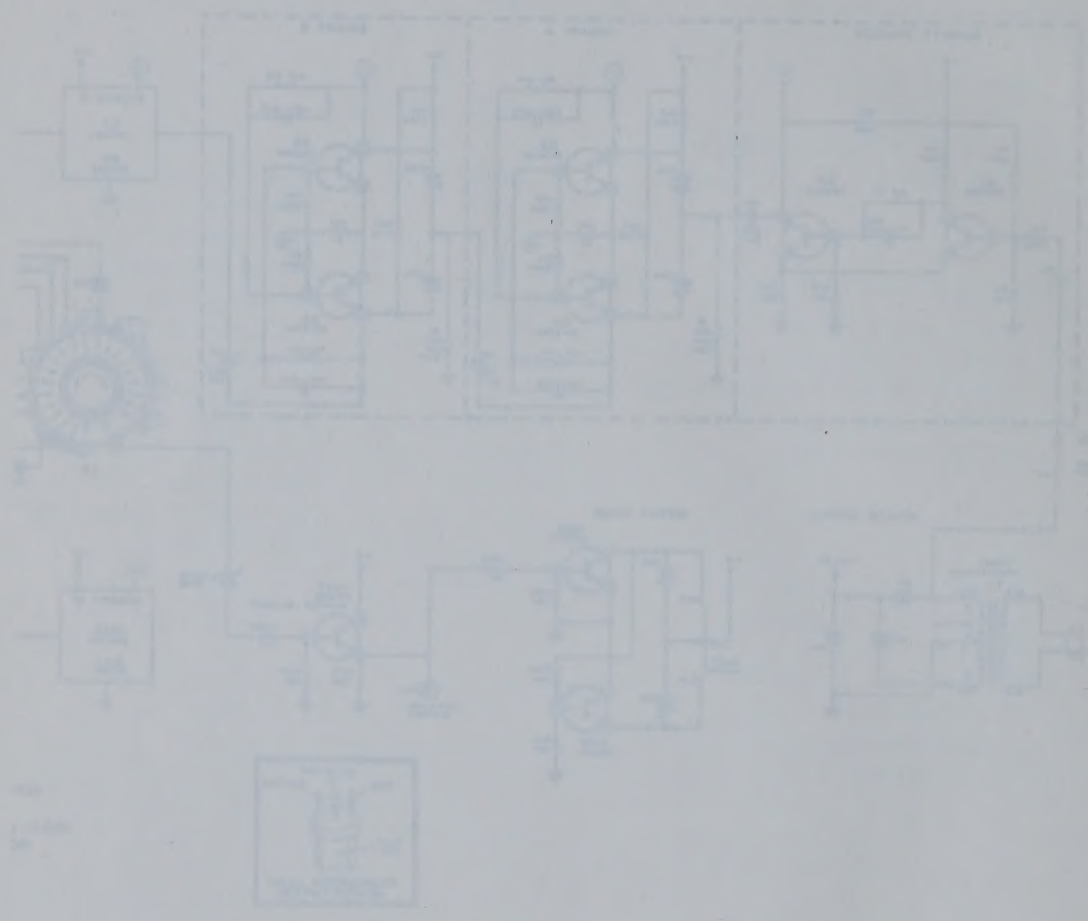
PART No.	DESCRIPTION
CAPACITORS	
21-21	200 μμf disc
21-36	.002 μfd disc
25-123	2 μfd 25 V electrolytic
25-111	1000 μfd 15 V electrolytic
DIODES-TRANSISTORS	
56-16	1N751 zener diode
56-26	1N191 crystal diode
57-29	750 ma 100V PIV silicon diode
417-118	2N3393 transistor
417-94	2N3416 transistor
HARDWARE	
250-162	6-32 x 1/2" screw
250-93	8-32 x 1/4" setscrew
252-3	6-32 nut
252-7	Control nut
254-1	#6 lockwasher
254-4	Control lockwasher
253-35	Fiber washer

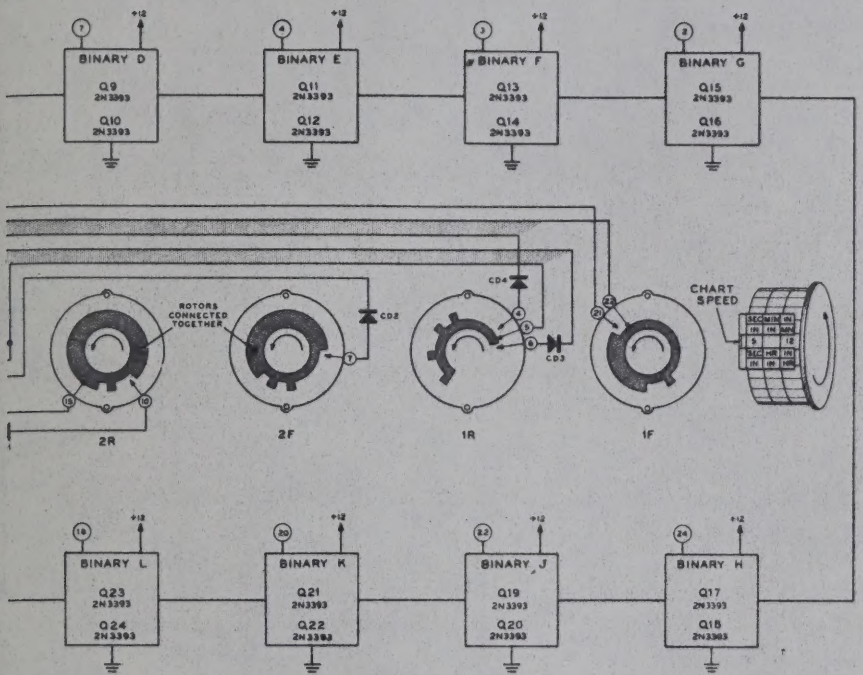
PART No.	DESCRIPTION
MISCELLANEOUS	
204-708-1	Speed switch bracket
462-226	Speed switch knob
63-417	Speed switch
54-166	Power Transformer
420-37	Chart motor
420-38	Chart motor gear 26 tooth
451-57	25 tooth gear
451-60	30 tooth gear
390-153	Rear label (1 extra)
390-154	Front label (1 extra)
390-167	Speed switch label (1 extra)
	Manual (See Page 1 for part number.)


SCHMITT TRIGGER
BINARY A
BINARY B
BINARY C
BINARY M
Q1 2N3393
Q2 2N3393
Q3 2N3393
Q4 2N3393
Q5 2N3393
Q6 2N3393
Q7 2N3393
Q8 2N3393
Q25 2N3393
Q26 2N3393
Q27 2N3393 EMITTER FOLLOWER
Q28 2N3416
Q29 2N3416
S1
EXTERNAL SIGNAL INPUT
INT
EXT
COM.
POWER SUPPLY
POWER TRANSFORMER T1
105-125 VAC 60 CPS
12.5V AC
+12V DC
MOTOR DRIVE
CHART MOTOR
(AUXILIARY OUTPUT)
ZENER DIODE
3R
TRANSISTOR LEAD IDENTIFICATION
COLLECTOR
BASE
EMITTER
FLAT SIDE

WAVEFORMS


Q1 BASE
Q2 BASE
Q3 THRU Q28 BASE
Q27 BASE
Q1 COLLECTOR
Q2 COLLECTOR
Q3 THRU Q28 COLLECTOR
Q27 EMITTER

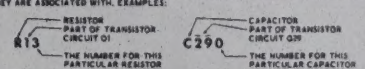




EMATIC OF THE
HEATH
PEED CHART DRIVE
DEL EU-20-26

NOTES:

1. ALL RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1000).
2. ALL CAPACITOR VALUES ARE IN μf UNLESS MARKED OTHERWISE.
3. *THIS RESISTOR IS ON BINARIES A, B, C, D, E, AND F ONLY.
4. WAVEFORMS TAKEN WITH A DC OSCILLOSCOPE FROM THE POINT INDICATED TO COMMON GROUND.
5. ⏚ THIS SYMBOL INDICATES COMMON GROUND THAT IS INSULATED FROM THE CHASSIS.
6. WAVEFORMS TAKEN WITH SWITCH S1 AT INT. AND CHART SPEED SWITCH FULLY CLOCKWISE.
7. CHART SPEED SWITCH SHOWN IN FULL CLOCKWISE POSITION AS VIEWED FROM THE KNOB END OF THE SHAFT.
8. ◯ THIS SYMBOL AROUND A NUMBER MEANS THAT THIS POINT IS CONNECTED TO THE LUG WITH THE SAME NUMBER ON WAFER 3R OF THE CHART SPEED SWITCH.
9. RESISTORS, CAPACITORS, AND DIODES ARE NUMBERED ACCORDING TO THE TRANSISTOR THEY ARE ASSOCIATED WITH. EXAMPLES:



10. BINARIES C THROUGH M ARE SHOWN IN BLOCK FORM. EACH OF THESE BINARIES HAS THE SAME CIRCUIT AS BINARY A.
11. REFER TO THE CIRCUIT BOARD X-RAY VIEW FOR THE PHYSICAL LOCATION OF THE PARTS ON THE CIRCUIT BOARD.